Accounting for genotype – nutrition interactions when optimising the composition of feeds for commercial broilers

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Abstract. A number of trials using different levels of balanced protein have shown significant and economically important differences in the response of two commercial broiler strains. At deficient levels one strain consistently increased feed intake and therefore grew more than the second strain, which exhibited a decline in intake on these feeds. However, the strain whose intake declined at low protein contents showed continuing improvements in response to protein levels higher than those normally recommended. These differences in response to dietary protein content are of considerable importance when optimising feeds for these strains. It is clear that responses need to be strain-specific if these are to be of value when optimising poultry feeds.

Keywords: genotype-nutrition interaction; broilers; feed composition; optimisation

Introduction

The main principle applied when predicting food intake of growing broilers, using the theory of Emmans (1981) and Emmans and Fisher (1986), is that the birds will attempt to consume sufficient of the food on offer to meet the requirements for the first-limiting nutrient in the feed. Thus, when the protein content of a feed is reduced consumption will increase until a point is reached where intake is constrained either by gut capacity or because the bird cannot lose sufficient heat, generated by the feed, to the environment to maintain a constant body temperature. As the dietary protein content continues to decrease below this point food consumption decreases, in part because intake of protein is insufficient to sustain adequate growth. Numerous examples have been published that confirm this theory (e.g. Clark *et al*., 1982; Burnham *et al*., 1992). One consequence of a reduction in dietary protein content is an increase in fatness (Gous *et al*., 1990).

This theory has been successfully incorporated into a simulation model that accurately predicts the food intake and growth of different strains of broiler (EFG Software, 2006). For the model to predict food intake accurately it was assumed that the genotype could be adequately described in terms only of its mature protein weight, rate of maturing and lipid:protein ratio at maturity (Emmans, 1989). As a result, numerous trials have been conducted in which genotypes have been characterised in this way (Hancock *et al*., 1995; Gous *et al*., 1996 and 1999). However, some recent trials conducted in the UK and in South Africa have shown significant and economically important differences in the response of commercial broiler strains to balanced protein (Kemp *et al*., 2005; Berhe and Gous, 2005).

This paper describes the results of these trials and suggests how feed intake prediction models might take account of these differences such that optimisation procedures may continue to be used to determine the most profitable feeds and feeding programmes for each strain. The differences between strains in their response to balanced protein are too great to be ignored.

Materials and methods

In the trial by Kemp *et al.* (2005) (referred hereafter as trial 1) day-old chicks from two commercial strains, A and B, were obtained from the same hatchery. Parents were 37 and 40 weeks of age respectively and chick weights 42.3 and 43.8g. The trial design comprised two strains, two sexes and five ideal protein (BP) levels in a factorial design with four replicates per treatment each of 90 chicks. Light (about 15 lux) was provided 23 (0-7d), 20 (8-21d) and 23 hours per day.

Dietary BP levels were defined by digestible (dig) lys levels as proportions (0.8, 0.9, 1.0, 1.1 and 1.2) of the recommended reference levels (Aviagen, 2002) in starter crumbles (0-10d), grower pellets (11-28d) and finisher pellets. Reference levels of digestible Lys and AMEn (g/kg//MJ/kg) were 12.7//12.6; 10.8//13.3 and 8.8//13.5 in starter, grower and finisher feeds respectively. Minimum levels of digestible amino acids were related to dig. lys as recommended in Aviagen (2002). Feeds were formulated using wheat, soybean meals, maize germ meal, sunflower meal and some fishmeal, together with L-lysine HCl, DL- methionine and L-threonine, to achieve the desired amino acid balance. Feeds and water were offered *ad libitum*. No growth promoter or coccidiostat was included in the feeds. Chicks were vaccinated against coccidiosis (Paracox-5, Schering-Plough Animal Health) at day-old. This trial was terminated at 46d.

In the trial by Berhe and Gous (2005) (trial 2) a similar procedure was followed, using day-old chicks (weighing 40.3 and 45.3g respectively) from the same two commercial strains, although not necessarily the same generations, as those used by Kemp *et al*. (2005). Six levels of BP were used, from 11.9 to 16g digestible lys/kg in the crumbled starter (0 to 21d) and from 7.9 to 11g/kg in the pelleted second phase, from 22 to 42d, at AMEn contents of 12.6 and 13.0MJ/kg respectively. The feeds consisted of maize, soya full-fat and oilcake, sunflower oilcake, fishmeal, wheat bran, L-lysine HCl and DL methionine. Zinc bacitracin and a coccidiostat were included in the feeds.

In both trials records of bodyweight, feed intake, body composition and other factors were maintained throughout. Mortality data included birds culled because of leg defects.

Results and discussion

In both trials strain B was significantly heavier than strain A at all BP levels up to 21d. By 32d, the responses of the two strains had crossed over in trial 1, but in trial 2 growth rates from 22 – 42d were identical in both strains (Table 1). At deficient BP levels strain B was clearly faster growing than strain A whilst at the recommended BP level the strains were similar in trial 1, but only at 42d in trial 2. At high BP levels strain B stopped responding and even showed a decline in growth rate in trial 1, whilst strain A continued to respond to the highest level used, with a higher breast meat yield than strain B.

Table 1 Responses in gain and food intake of two commercial broiler strains to feeds varying in ideal protein (BP) content during two periods of growth (trial 2).

BP (relative)	Period 0-21d				Period 22 – 42d			
	Strain A		Strain B		Strain A		Strain B	
	Gain, g/d	Food, g/d	Gain, g/d	Food, g/d	Gain, g/d	Food, g/d	Gain, g/d	Food, g/d
0.7	29.3	40.0	33.6	45.4	59.5	123	59.6	121
0.8	33.9	43.7	37.2	47.5	60.9	126	59.1	118
0.9	34.2	44.0	37.3	47.6	61.3	126	61.1	117
1.0	33.6	43.4	37.5	47.1	62.3	127	62.0	117
1.1	33.5	43.2	37.4	47.3	62.5	127	62.2	116
1.2	34.0	43.9	37.5	47.8	62.5	128	63.2	116
R.M.S.	0.90	2.51	0.90	2.51	12.9	19.4	12.9	19.4

In both trials strain B consistently increased feed intake as dietary BP was reduced and therefore grew better than strain A, which exhibited a decline in intake on these feeds (Fig. 1). However, in trial 1 strain A showed continuing improvements in response to protein levels higher than those normally recommended. Given that the response in food intake to feeds marginally deficient in protein differs so considerably between the two strains the optimum amino acid content for each of these strains is

unlikely to be the same. Yet without modifying the description of the two genotypes used here, the simulated food intake and growth of the two strains, in response to the changing dietary BP content, would be the same. Some mechanism needs to be used to alter the way in which genotypes respond in food intake to feeds deficient in an essential nutrient.

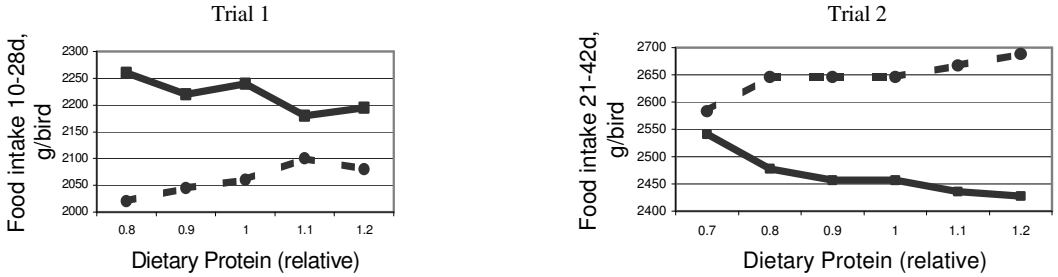

Figure 1 Response in food intake of two strains of broilers to increasing dietary balanced protein contents. Left graph from Kemp et al. (2005), right graph from Berhe and Gous (2005). Strain A represented by dashed line; strain B, solid line.

Both strains appeared to respond in a similar manner to a decline in dietary protein content up to 14d of age, the differences only becoming particularly apparent around 21 d. It is possible to simulate this effect by adjusting the ratio of lipid to protein in the gain, which enables birds to overconsume energy to varying extents when faced with a feed marginally deficient in protein. A genotype that is unable to store excess energy in the form of lipid, when faced with a feed marginally deficient in an essential nutrient, would instead need to lose this energy as heat, thus being less likely to be able to cope with deficient feeds, especially at high temperatures. The period of growth when the desired food intake is most likely to be constrained in this way is when the birds are growing at their maximum rate, namely between 21 and 35 d of age. In Table 2 the simulated results of a protein response trial are presented for lipid: protein ratios of 1.0 and 2.0 to illustrate the point. All inputs to the model other than this ratio were identical in both simulations.

Table 2 Body weight and food intake of two simulated strains of broiler, varying in the maximum permitted lipid: protein in the gain, over two periods of growth, and five dietary protein contents.

Dietary Protein	Maximum lipid: protein in gain = 1.0				Maximum lipid: protein in gain = 2.0			
	0 – 14d		21 – 35d		0 – 14d		21 – 35d	
	Weight gain, g/d	Food intake, g/d	Weight gain, g/d	Food intake, g/d	Weight gain, g/d	Food intake, g/d	Weight gain, g/d	Food intake, g/d
High	26.7	31.2	91.6	170	28.2	32.7	92.4	173
2	24.4	30.2	89.9	175	26.9	32.8	95.2	181
3	20.6	27.7	70.3	163	24.1	31.7	92.7	200
4	15.6	23.9	64.6	146	18.9	27.8	87.1	184
Low	13.4	22.0	49.7	125	16.0	25.4	74.0	170

The values assigned to the maximum lipid:protein in the gain in the two simulated strains above were not designed to match precisely the two strains used in the trials reported: rather, the objective was to demonstrate the principle of altering this ratio on the response in food intake when the content of an essential nutrient is reduced in the feed. Food intakes in the first 14-d period for both scenarios appear to follow the same trend, namely, to decrease with BP content. In the second period differences in response are similar to those observed between strains in the two trials, with food intake increasing marginally as BP content decreases, with the maximum lipid:protein in gain ratio of 1.0, but considerably more in the other case with a higher ratio. Weight gains follow the pattern of food intake, differences between the highest and lowest BP contents being 42 g/d when the lipid:protein ratio in the gain is low, and only 18 g/d when this ratio is doubled.

These findings have important commercial implications. The protein content that will maximise profit has to be determined on economic grounds, taking account of bird responses defined in experiments such as these. If the mechanism responsible can be identified then simulation and optimisation models may be used to determine the composition of the feeds that will optimise

performance, i.e. to maximise profitability, and these would differ between strains that respond differently to feed BP content: the feed protein content that maximises profitability for the strain that is capable of greater lipid: protein in the gain is likely to be lower than for the strain that cannot deposit excess energy as body lipid. Using the EFG broiler nutrition optimiser (EFG Software, 1995) to determine the feed composition that will maximise margin over feed cost, using a starter to 21d and a grower from 22 to 35d, the optimum lysine content in the starter was the same for both simulated strains (1.31g digestible lysine/kg feed), but the optimum grower feeds differed markedly: 0.80g lysine/kg for the strain capable of depositing high lipid contents in the gain *vs*. 1.03g lysine/kg for the other strain. That the optimum lysine content was the same for both strains in the starter period is a reflection of the reality that both strains respond similarly to feed protein content in this period. Real differences in the responses of the two strains to protein in the grower period are reflected in the optimum lysine contents for maximising profitability.

Mortality was not considered when determining the optimum lysine contents in the feeds for the two simulated strains. However, strain B in trial 1 exhibited a significantly higher mortality than did strain A; whereas mortality in strain A remained at around 3.6% over all protein contents, mortality in strain B increased from 8.5 on the lowest to 16.8% on the highest protein feed. Such an effect cannot be simulated mechanistically, but should nevertheless be incorporated into any model in which the protein content of the feeds is to be optimised. It is clear that responses need to be strain-specific if these are to be of value when optimising poultry feeds.

References

AVIAGEN 2002**.** Ross Broiler Management Manual. See www.aviagen.com (accessed June 2006)

BERHE, E.T. and GOUS, R.M. 2005. Effect of dietary protein content on allometric relationships between carcass portions and body protein in Cobb and Ross broilers. *South African Branch of WPSA Conference*, Pretoria.

BURNHAM, D., EMMANS, G.C. and GOUS, R.M. 1992. Isoleucine requirements of the chicken: the effect of excess leucine and valine on the response to isoleucine. *British Poultry Science,* **33**: 71 – 87.

CLARK, F.A., GOUS, R.M. and MORRIS, T.R. 1982. Response of broiler chickens to well-balanced protein mixtures. *British Poultry Science,* **23**: 433 – 446.

EFG SOFTWARE 1995. See www.efgsoftware.com (accessed June 2006).

EMMANS, G.C. 1981. A model of the growth and feed intake of *ad libitum* fed animals, particularly poultry. In *Computers in Animal Production*. pp. 103 – 110. Occasional Publication No. 5. British Society of Animal Production.

EMMANS, G.C. 1989. The growth of turkeys. In *Recent Advances in Turkey Science. pp 135 – 166.* (Nixey, C. and Grey, T.C. eds). London, Butterworths.

EMMANS, G.C. and FISHER, C. 1986. Problems in nutritional theory. In *Nutrient Requirements of Poultry and Nutritional Research*. pp 9 – 39. (Fisher, C. and Boorman, K.N. eds), London, Butterworths.

GOUS, R.M., EMMANS, G.C., BROADBENT, L.A. and FISHER, C. 1990. Nutritional effect on the growth and fatness of broilers. *British Poultry Science*, **31**: 495 – 505.

GOUS, R.M., MORAN, E.T. JR., STILBORN, H.R., BRADFORD, G.D. and EMMANS, G.C. 1999. Evaluation of the parameters needed to describe the overall growth, the chemical growth, and the growth of feathers and breast muscles of broilers. *Poultry Science,* 78: 812-821.

GOUS, R.M., PYM, R.A.E., MANNION, P. and WU, J.X. 1996. An evaluation of the parameters of the Gompertz growth equation that describe the growth of eight strains of broiler. *Australian Poultry Science Symposium*, Vol. 8, 174 - 177, University of Sydney, Sydney, NSW.

HANCOCK, C.E., BRADFORD, G.D., EMMANS, G.C. and GOUS, R.M. 1995. The evaluation of the growth parameters of six breeds of commercial broiler chickens. *British Poultry Science,* 36: 247 - 264.

KEMP, C., FISHER, C. and KENNY, M. 2005. Genotype – nutrition interactions in broilers; response to balanced protein in two commercial strains. *15th European Symposium on Poultry Nutrition*, Balatonfüred, Hungary, pp 54-56.